Urban block paving in The Netherlands

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Introduction

TO COMPLY with the invitation of the Conference Steering Committee on this, the First International Conference on Concrete Block Paving, the author has gone more deeply than ever before in his career into the practice of concrete block paving. In some respects, the title of this paper is too broad. What is described is the application of small-element pavements in the city of Amsterdam, but what is said applies to other Dutch cities. The history of small-element pavements is about the same in all Dutch cities and villages, and indeed the drastic social changes after the Second World War have had more or less the same influence on the development of road networks in most municipalities.

Amsterdam is the capital of the Netherlands and has the largest population of any Dutch city, The peak of 875,000 was reached in 1958 but during the last ten years the population has decreased to 720,000.

Holland is the western part of the Netherlands and for the greater part consists of peat-bog areas which offer a poor sub-soil on which to build cities. Every building, large or small, is founded on piles which have to be 15 to 20 m long because only at that depth can a good bearing sand-layer usually be found. For the construction of new urban developments the land has usually been filled with sand which geologically is of marine origin and dredged from existing or artificial lakes. In order to protect the environment, concessions for the dredging of sand arc no longer granted or extended by the authorities, so that for the last few years the sand has often come directly from the North Sea. Il is very uniformly graded and generally contains not more than a few % of silt (parts <63 µm). The filling up is done either dry by lorry, or wet by pipeline. In hot h cases considerable settlements occur which can vary from 0.50 to 1.00 m or even more.

History

Since the middle ages the streets in Amsterdam have been paved with small-elements, Until well into the 19th century traffic moved on steel wheels or on sleds. At that time natural stone was the only material which had sufficient resistance to the wearing action of the traffic, and so the carriageways were paved with cobbles of natural stone. The footpaths were paved with bricks (Figure 1) for two reasons/thc bricks were more comfortable to walk on because of their rectangular shape, and second they were cheaper than the natural stone which had to be imported from neighbouring countries.

Several large and small rivers flow to the sea through the western Dutch delta-area. Along these rivers a number of brick factories could and can still be found, producing bricks from clay excavated from the outer marches.

Thus, different shapes (formats) came into use and were named after the place of origin. The most common were the Ijssel-, Vccht-, Rijn-and Waalformat.so called after the rivers Ijssel, Vecht, Rijn and Waal. The biggest of these was the Waalformat, 195 x 48 x 85 mm, and it became the most common type of paving brick (Figure 2). When, at the end of the 19th century, the rubber lyre was more and more used for vehicles, first as cushion tyres and later as pneumatic tyres there was less need for natural stone as a paving material. At the turn of the century, large town developments introduced brick paved streets,

With the increase in the volume and speed of motor traffic, it became obvious that the Waalformat had some disadvantages. Pavement deformations included “turning-over" and “creeping", and to prevent these the thickness was increased from 48 mm to 64 mm, and the new size 195 x 64 x 85 mm was called the "thick format".

This development continued and in the second quarter of the 20lh century the so-called cobbkformat 195 x 92 x 85 mm. came into use. In contrast to the older formats, the cobbleformat is not so rectangular, with the result that the lateral faces are not perpendicular to the bottom-face. It is this type of paving-brick that has been used in large quantities for town developments between the two world wars, and especially since 1945.



Figure 1: Cobbles on the carriageway, bricks on the foot path.

Concrete blocks

After the initial recovery from war damage, expansion started in the Netherlands as it did in other European countries which would lead to green fields developments. The population increased in a very short time whilst families became smaller, so that the housing stock became incompatible with the size and number of families. Increasing prosperity created a demand for larger dwellings, and last but not least the number of houses per square kilometre decreased drastically. From a density of 200 per hectare in the 19th century, densities in the newly-built areas sank to 80 per

hectare, All these (actors lead to an enormous growth of the paved area per inhabitant (Table 1), the total paved area increasing between 1945 and 1979 by a factor 2.4,

Buildings, bridges and other constructions are carried on piles and undergo no settlement whereas pave–ments settle from 0.30 to 0.60 m (in Amsterdam) and so it appeared sensible to continue the use of small element pavements. Compared to the cost of the materials, the cost of the labour was low, and so it was relatively cheap to raise the pave-ments from time to time by simply taking up the pavements and relay-ing them with the same material after infilling with sand. In the case of asphalt-pavements the original surface materials would have been lost.

As mentioned already, the circumstances are similar in many Dutch cities, and so a large demand for paving bricks was generated; a demand to which the producers had no answer. The shortage of paving bricks was accentuated by the large quantities of bricks that were needed for the construction of houses. The latter use was so important that it became more profitable for the manufacturers to make conventional bricks, since they were cheaper to produce than paving bricks (Figure 3). This was the market-situation into which the concrete block Was introduced as a paving material: as an alternative to bricks, and not as a new construction material.

The Annual Report for 1955 of the Public Works Department of Amster-dam contains the following:

"The market-position for paving bricks stayed critical during the year under review. The producers delivered 10.6million bricks cover-ing hardly half the need ...

...As a consequence of the scarcity during the year under review in more cases light asphalt-constructions have been applied in residential streets and other roads with lighter and not intensive traffic on which normally a new brick pavement should have been applied.

"It will be necessary to start the use of additional materials as an alter-native for bricks. In this context some smaller batches of concrete blocks have already been purchased, a substitute that has proven its suitability on several sites in the years after the war."

From the 1956 Annual Report the next passage is quoted:

"The persistent scarcity of bricks had a restraining influence on the execution of pavement-works.

"As mentioned in the report on 1955, a good substitute is required as a consequence of the scarcity of bricks. Concrete blocks, a material that has been brought into the market for several years, can be considered as a useful alternative. Some experiments with concrete blocks have been carried out. The results of the experiments so far are in accordance with expec-tations and the use of concrete blocks can be considered as justified in every respect, although for the time being concrete blocks can be considered only as a substitute for bricks."

This long, maybe even tedious, historical description was intended to demonstrate that concrete blocks have not been introduced as a new paving material for which particular and unknown design and construc-tion techniques were required. It may also be clear why in Amsterdam rectangular shaped concrete blocks are used, to the almost complete exlusion of other shapes.

TABLE 1:

Year	*Number of Inhabitants*	*Area (m^2) per inhabitant*		
		Carriageways	*Footpaths*	*Total**
1930	757,400	6.64	3.26	9.90
1940	800,600	7.03	3.75	10.78
1950	835,800	7.10	3.78	10.89
1960	869,600	9.16	5.27	14.53
1970	831,500	14.33	8.06	22.39
1978	718,600	18.36	10.25	28.61

***** *Not including parks.*

Dimensions and quality

For the purpose of delivery contracts, specifications were made describing the properties that producers had to meet. On a national level there were no specifications available. Since 1956 there have been small variations in size, but the most usual format is 213 x 105 x80 mm. For some time the Amsterdam specifications prescribed 220 x 110 x 80 mm but it became evident that the width and the weight of these blocks reduced the production of the paviors. The specifications changed the sizes into 200 x 100 x 80 mm. This proved to be an Improvement. Later, the Amsterdam specifications were brought into line with the national NEN 7000. In (he meantime it must be said that, at the time of their appearance, concrete blocks were of cobble-format. The difference between brick and concrete block is that the latter has plain-parallel lateral faces. The specifications for strength were formulated in a way other than in the NEN 7000. After calculation it became clear that the requirements were in accordance with each other. Therefore, the NEN 7000 became operative for deliveries to the municipality of Amsterdam in the early seventies.

Later developments

From the foregoing it is evident why

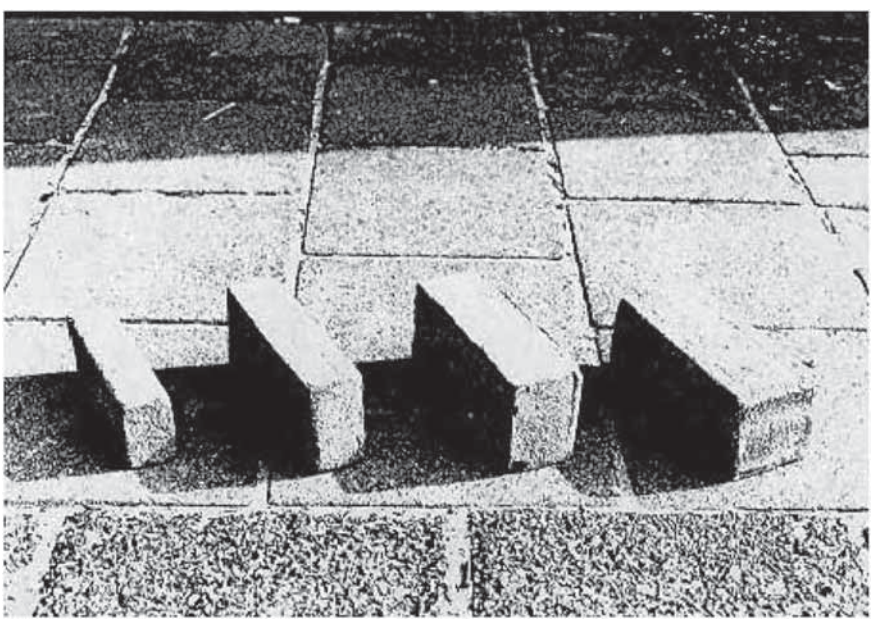


Figure 2: Bricks. Left to right: Yssd, Want, Thick, Cobble formats.

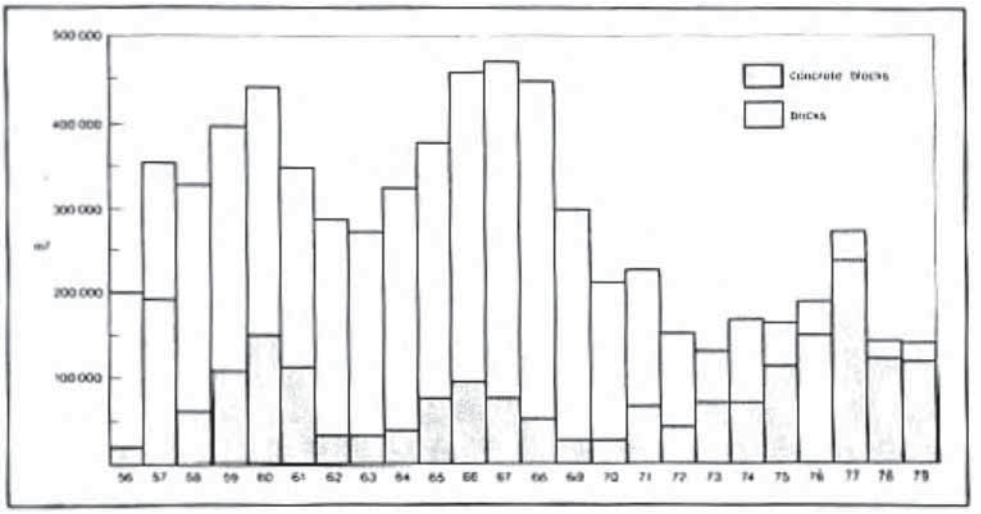


Figure 3. Use of bricks and concrete blocks—1956 to 1979.

small element pavements were preferred in town-extensions. From the quoted annual reports it became obvious that residential streets were being provided with asphalt pavements because of the scarcity of bricks, mainly in the older quarters where no further settlement was to be feared The conclusion can be drawn that such a policy was not usual until those days. The residentsagreed with the new type of pavement in their streets. Frequently people even requested asphalt instead of bricks.

In the later sixties more and more resistance grew against the continuous increase of motor traffic, strangling city-life. At the same time an antipathy developed against asphalt pavements and all large scale technology, as it identified with motor traffic. A nostalgia for old-fashioned things was bom, and more and more people arc now asking for small clement pavements when the streets where they live are to be relaid.

To accommodate this nostalgia, block producers brought the concrete thick format into the market and even the concrete Waal format (Figure 4). To make the concrete blocks look more like bricks efforts have been made successfully to give the blocks more “shaded" instead of the usual monotonous colouring.

Design

From the foregoing it will be clear that, in the Netherlands, neither the user nor the designer regards the concrete block as a new phenomenon. In general the user will not even be aware of the difference. Designers certainly did not think about the difference There was no reason to treat concrete blocks in any way different from bricks. Consequently, their application is based on experience only. No research has been carried out. either theoretically or practically, and as a consequence no design methods have been developed And to be honest, it makes no sense to do any research on things when everything is known and common The practice of centuries has been the experiment.

Taking this all in all. it does not give the engineer a basis from which to prognosticate the behaviour of concrete block pavements for new applications under new circumstances Therefore, it is desirable that more research be earned out theoretically as well as practically.

Experience in the Netherlands is that smal l element pavements are less suitable for roads loaded with heavy traffic, expecially when traffic speeds exceed 60-70 km/h.

High speed heavy traffic causes vertical and horizontal deformation.

In Amsterdam a road classification is in use for design purpose which is based upon the Shell-design method. There are 5 classes, ranging from Class I for heavy and intensive traffic to Class V for residential streets. Small element pavements are not used for Classes I and II,

Based upon experience it can be stated that the construction shown in Figure 5 is suitable for Class III traffic (1000 commercial vehicles per lane per day)

The basecourse consists of granular material graded in accordance with specification. The sand course between base course and block pavement consists of the same fine and uniformly graded sand as l he sand-bed beneath the base.

Better results can be obtained with the use of crushed sand, which reduces carriageway deformation (Figure 6).

For Class IV, the base course can be 0.15 m just as for Class V. For the latter the base course is omitted when the carriageway is wider than 4 m because the traffic does not follow the same track.

No distinction is made between bricks and concrete blocks. It is questionable whether this is justifiable because it must be said that the performance of concrete blocks is superior to that of bricks, from the point of view of construction. The

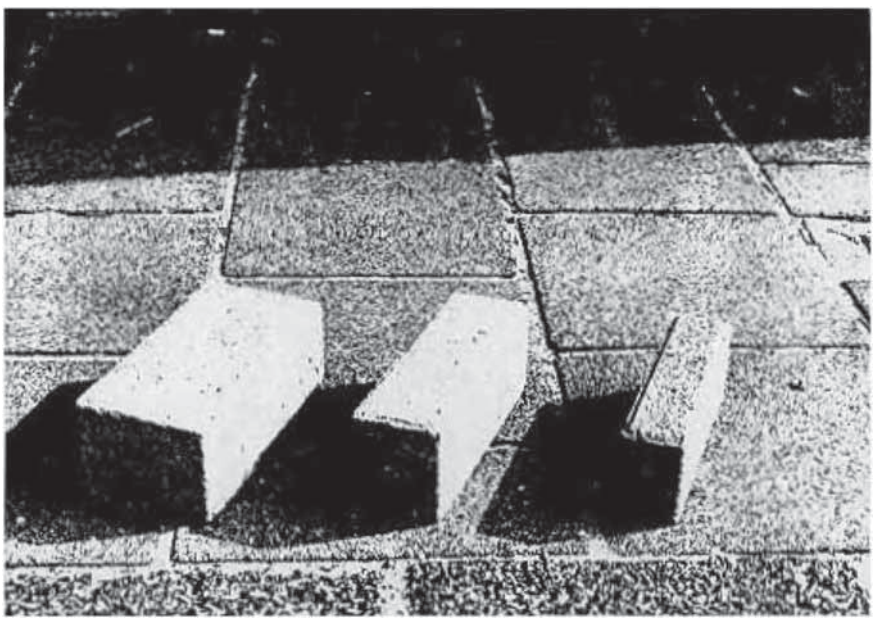


Figure 4: Concrete blocks. Left to right: Cobble, Thick. Waal formats

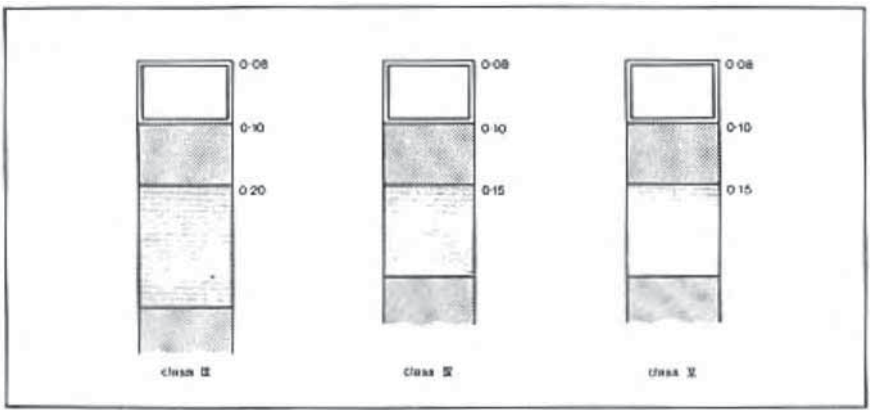


Figure 5: Classes III, IV and V compared.

better performance is due to smaller tolerances, better steadiness in sizes and good rectangular shape of the blocks.

Special attention must be paid to the drainage of the pavement.

In the first place there must be sufficient crossfall to enable the rainwater to run off quickly and not remain in puddles on the surface. Even when good surface-drainage has been provided some of the rainwater will penetrate into the joints. Therefore the sandbed as well as the base course and the sandcourse will need to have good draining properties so that there is no risk of soaking otherwise damage can easily occur, specially in the winter-time during frost periods

Applications

Small element paving is used in areas where further settlement is expected and where the pavement will need to be re-laid after raising (Figure 7). It is also used in residential streets subjected to light traffic (Class V), Many parking places are paved with concrete blocks or bricks because of static loads

It must be admitted, however, that in Amsterdam it is the long-term intention to reduce the share of small element pavements in the total paved area, because at present their maintenance costs are twice those of asphalt pavements.

One of the main causes of maintenance work is the repeated breaking up of the pavements to permit work on underground cables and pipes. Streets with a primarily estate function need to be broken up less frequently for this purpose than more important streets. Although small element pavements can he repaired more cheaply than asphalt pavements, damage will be more severe on the long run and complete repaving will be needed sooner.

At present there is hardly any difference in the initial costs of concrete block pavements and asphalt pavements, but the tremendous increase of labour costs during the last 20 years has made a complete repaving (with the present blocks) more expensive than an asphalt overlay. When the first concrete blocks were laid in Amsterdam in 1956 the price of those concrete blocks and the price of bricks were equal. In the course of the years bricks grew more expensive because of the more labour-intensive production (Figure 8). Production of bricks also demands more energy, which is reflected by the increase of prices after 1973. At present, prices of bricks are 2½ times those of concrete blocks.

Additionally bricks are very scarce, and nowadays it is very difficult to get delivered more than ½ million bricks per year (compared to the 21 million delivered in 1968) (Figure 9). For these reasons it was decided in 1975 in Amsterdam to use bricks only along the older canals in



Figure 6: Concrete blocks newly laid on the carriageway. Old bricks used in the parking lane. Crushed sand spread on the surface.



Figure 7: Thick format concrete blocks in New Town extension

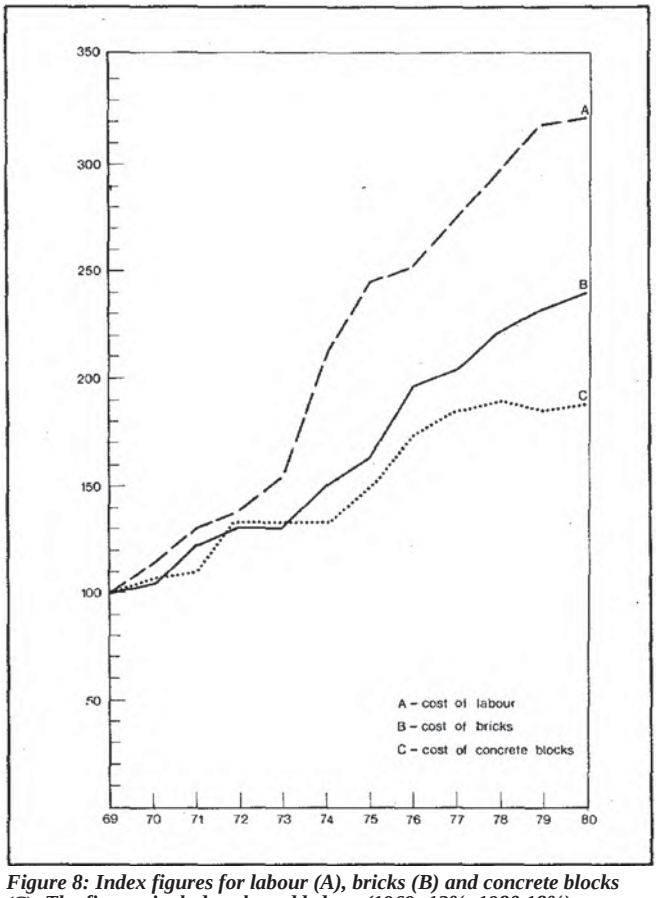


Figure 8: Index figures for labour (A), bricks (B) and concrete blocks (C). The figures include value added tax (1969: 12%, 1980 18%).

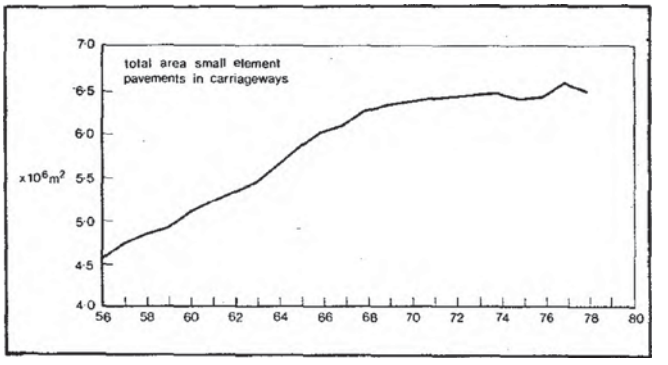


Fig 9: Growth in the use of small element pavements in carriageways.

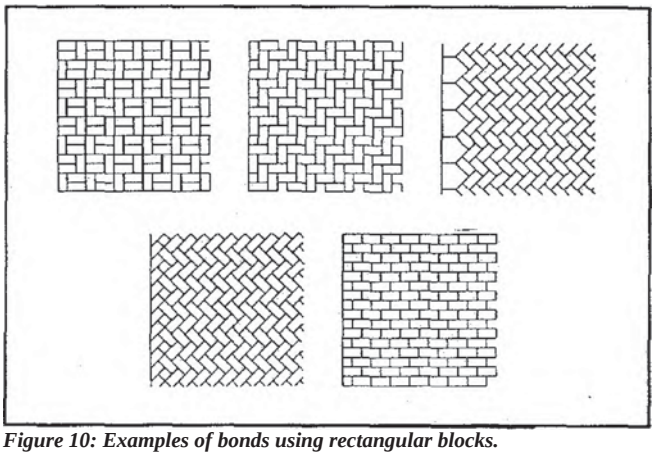


Figure 10: Examples of bonds using rectangular blocks.

the historic inner city, where architecture and town-scape demand the use of bricks. In all other cases, only concrete blocks are used for small element pavements of carriageways.

Bondings

Small element pavements of rectangular blocks can be paved in different bonds (Figure 10). Stretcher bond is the most simple but it is prone to deformation like creep. For that reason in Amsterdam twilling-bond is the most used and most successful type of bonding, the blocks being placed at 45° to the traffic. Block cutting at the edges of the roads can be avoided by the use of so-called "bishop-hats". On parking areas elbow bond is often used, which is the same as twilling-bond but at right angles to traffic. Block bond is sometimes used in ornamental pavements on pedestrian areas and also in temporary work. It is not used for intensive traffic.

In curves, where two directions of block bonding meet at an angle, bonds have to be modified in a special way. For good results skilled paviors are needed.

Cross-section

The cross-section of the pavement must enable rainwater to run off rapidly into gutters and drain holes. The most simple cross-section shape is the roof-profile, in which the two halves of the road are laid in planes at 3% to the horizontal, meeting each other at the top, which is rounded. Because even small settlements can lead to puddles in the surface, the roof profile does not give a good performance.

Other shapes are therefore used, the most common being the modified tunform profile (Figure 11). The kerbs along the horizontal sides of roads are laid with a longitudinal slope of 0.5%. Drains are placed at 20 m intervals, and the differences in gutter levels are worked off within the outer 1 $^1/_2$ to 2 m of the cross section.

When the work is done by skilled paviors, it is sufficient to give only the crown-level or kerb-level on the construction drawings. The pavior knows how to handle the profile, and fine-screeding of the sandbed is not necessary.

Block laying

There are two different ways of placing the blocks by hand.

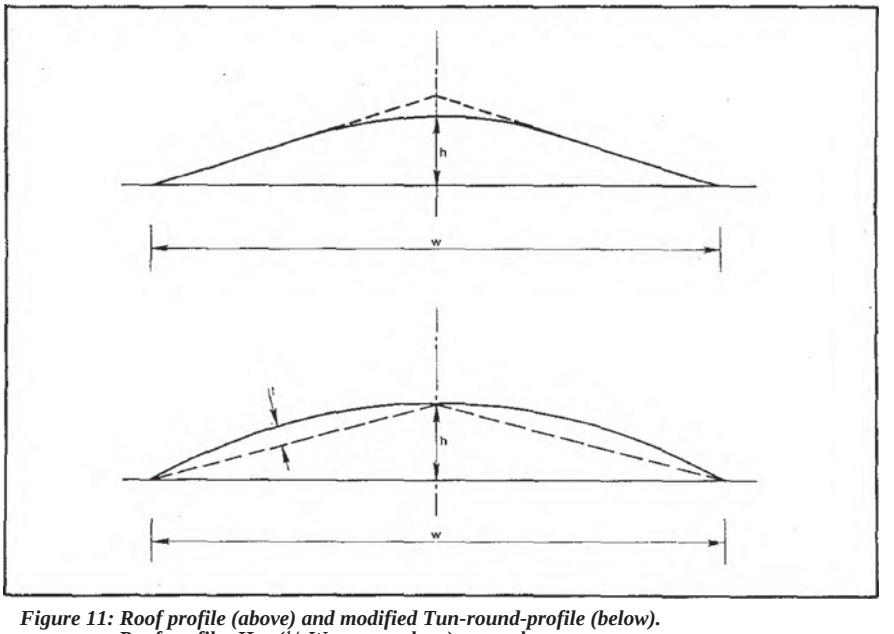


Figure 11: Roof profile (above) and modified Tun-round-profile (below).
Roof profile: $H = (^1/_2 W \times$ cross-slope) cross-slope.
Modified Tun-round-profile: $H = ^1/_2 W \times$ cross-slope. $t = ^1/_4 H$



Figure 12: Pavior working on a one-legged stoot



Figure 13: Pavior working on his knees.



Figure 14: A round-about more than 20 yean old, uicd by over 15000 vehicles per day until 1970.

The first is the traditional craft method used by paviors. In this method, the sandbed is sc reeded roughly, and the pavior places the blocks with his left hand. In his right hand he holds a pavior's hammer with which he finishes the sandbed and hits the block into place, thus seating it firmly. In the Netherlands, there are three common working positions for paviors: in Amsterdam he sits on a one legged stool; in Rotterdam he stands on his feet, bending down while paving; and in the rest of the country he kneels down. The pavior works backwards, thus having a good view of his completed work (Figures 12 and 13). It is usual for the pavior to work with one helper, and the average production of such a team varies from 50 to 75 m^2 per day. A skilled pavior can handle all types of materials and bonds, including a variety of ornamental bonds.

The second method is the "lay-down" method, in which the sand bed must be accurately sc reeded and compacted carefully in advance. After some instruction, most workers are able to lay the blocks in a proper way. They stand on the completed work, looking forward into the working direction. A man's production can range from 100 to 140 m^2 per day. This method is unsuitable without the dimensional precision of concrete blocks.

Efforts have been made to mechanize block-placing. Among these may be mentioned a block paving device developed in Amsterdam between 1965 and 1970 in co-operation with the city's Public Work's Department. The device was mounted on a pneumatic tyred roller and the prototype operated forabout two years. There were two reasons for stopping the experiment: (a) the equipment turned out to be usable for only 20% of all paving work, i.e. for new work paved in stretcher bond and in sufficient quantities; and (b) production costs were not lower.

When the blocks have been placed in position, the joints arc filled with sand, the best type being a well-graded crushed sand. A thin layer is spread on the surface and swept into the joints. Il may sometimes be necessary to repeat this operation, because a good filling of the joints is essential to keep a good bond and to prevent deformations. After the joints have been filled, the pavement is rolled to provide the final compaction, a 1500 kg vibrating roller or a 6 tons standard roller being the most common.

Transportation

In the Netherlands, most of the block factories are situated within a radius of about 100 km around Amsterdam.



Figure 15: Examples of block displacement in the direction of the traffic as a result of horizontal forces. The damage catalogue identifies the gravity as light, moderate or severe according to the degree of displacement. The proportion of damage is estimated as square metres of moderate / severe damage.



Figure 16: Examples of blocks cracked as a result of heavy traffic and/or insufficient base-course and/or insufficient strength. The gravity of the cracking is classified as moderate (left) to severe (right). The proportion of pavement damage is estimated as square metres of moderate/severe damage.

From the works, the blocks are transported by trailers which arc too big to manoeuvre in most urban streets, and so they are unloaded in the Road Department's central yard. The blocks arc transported from there to the working sites by smaller trucks. Loading and unloading are mechanized.

Central storage is necessary because storage on the site is not desirable. Paving blocks arc popular toys for children, especially when they arc stored near one of the many canals. Rut even if they do not find their way into a canal, stray blocks on the road surface are a danger to road users. Therefore, there is a tendency to supply working-sites with the qunlity for a day's production

in practice 70 to 80% of lite blocks arc stored on the yard before transportation to the sites; however this raises the price of the final product.

Training

In former times craftsmanship was passed from father to son. and even in these days the son often chooses his father's profession. Yet there is a difference Before the Second World War a boy started his training ns his father’s or uncle’s helper. After some years he was allowed (!) to practice paving-work during meal-intervals. Then, when there was a vacancy to be filled for a skilled pavior he could give proof of his skill to the surveyor.

Nowadays in the Netherlands boys start as an apprentice at the age of 16 or 17. Apprentice training lasts for five years, divided into a three-ycar and a two-year period. At the end of both periods there is an examination. covering both theory and practice. During the first period the apprentices go to school one full day per week, and do practical work as a group during I Ik other lour days. During (he second period, they work five days a week and go to school in the evening once a week

Apprentice systems are regulated by law in the Netherlands. Indentures, examinations and. in general, training-levels are controlled by a national body that lakes care of the administration of apprentices and sends counsels all over the country to keep contact with employers as well as apprentices, there arc also facilities for adults to become skilled paviors and they also do their examination under the responsibility of the national body. In the field of roadbuilding the SBW (Stichling Bevordering Wegenbouw

Foundation for the promotion of road engineering) takes care of all training facilities outside regular school institutions.

In the Netherlands, about hall of all the skilled paviors are employed by the municipalities and the other half by private employers. Unfortu-

nately, the number of apprentices coming forward cannot meet the need for skilled paviors, and so there is a lot of sub-standard work to be found. It is a physically demanding profession which most paviors do not sustain until retirement. In Amsterdam, paviors are discharged as medically unfit at the average age of 42, and there is a high migration rate to related trades.

And so, in spite of the generally high rate of unemployment, there is a shortage of paviors and no qualified pavior is unemployed. As it is forecast that the social acceptability of heavy work will decrease, this has been one of the reasons to propose to the city council a reduction in the proportion of small element pavements from 50% to 25% during the next few decades.

Lifetime and maintenance of small element pavements

The available figures justify the conclusion that the average lifetime of these paving materials is about 40 years, and that once in that lifetime a full-scale repair will be needed with re-use of the blocks. When a full-scale repair is carried out about 90 to 95% of the materials can be re-used.

It is not possible to draw separate conclusions for bricks and concrete blocks. The durability of a concrete block pavement depends on its use, as with other forms of construction. In Amsterdam there are roads paved with concrete blocks which are in excellent condition after 20 years, in some cases under very heavy traffic (Figure 14). From a maintenance point of view the greatest evil in city streets is the frequent breaking out of pavements to lay or maintain pipes and cables. Block pavements can be repaired well and easily after such disturbance, although some surface deformation may be expected because it is difficult to recompact the materials in the backfill to as high a degree as before. This is a problem with which municipal road engineers have learned to live. Spot repairs are relatively more expensive than full-scale repairs, since the output of a two-man paving team for this type of work is about half that for new work or for full-scale repaving.

In some cases the decision had to be taken to replace a brick pavement because it had a too low coefficient of friction. Bricks are easily polished by the traffic and as a result, on some streets, the skid resistance had fallen as low as 0.33 (with 86% slip of the measuring wheel at 50 km/h). A co-efficient of 0.51 is considered to be a minimum. During the 20 years that concrete block pavements have been in use, such a decision has never had to be taken for the same reason.

Until 1970 a great deal of the road network in Amsterdam was inspected once a year by a two-man inspection team who rated the service-ability using a simple visual system. The lowest serviceability was rated as “0” and the best “5”. Pavements rated at 0 had to be repaved.

As a consequence of the growth of the paved area, the yearly inspection had to be shared by more inspectors, and in this way the subjectivity of the assessment soon came to light.

Recently a new inspection and registration system has been under development. The road network is divided into about 12000 street parts, each indicated by a unique code.

The street parts are divided into functional parts such as footpaths, carriageways, cycle paths etc. and for each of these areas, the type of pave-ment, age of pavement, last inspection data, costs of daily maintenance etc., are recorded in a databank. All streets will be inspected once every two years in future, and properties and defects will be registered with the help of a damage catalogue. The system aims to eliminate subjectivity as far as possible (Figures 15 and 16). Measuring of flatness and friction will also be carried out. The intention is to have the system operational by the end of this year, and to complete it within the next three years.

In addition to the two-yearly inspection cycle there is another more frequent inspection that is more concerned with the identi-fication and repair of local defects. Because of budget restrictions a better budget control seemed desirable and a system had to be developed in such a way that an equal maintenance level could be reached in all of the seven city districts. In other words, road defects have to be identified with the same urgency class wherever they occur. A damage catalogue has therefore been set up giving an urgency classification of the most frequently-found defects:

Urgency 1 means: danger to road users.
Defect has to be repaired immediately.

Urgency 2 means: trouble for road users.
Defect has to be repaired within the next few weeks

Urgency 3 means: not serious.
Repair only if allowed by the budget.

The inspector records his findings on inspection forms. All data are put into the automated management information system and transmitted into working orders. Budget control is effected by monitoring the order, supply and amount of repair, including the costs.

Once a year the costs of repair per street-part are transmitted from the management information system to the road network databank, thus giving the financial consequences of the present servicability.

To give an idea: the maintenance expenses of the city of Amsterdam are:

For structural maintenance. Full scale reconstruction and overlays: Dfl. 40 million.

For daily maintenance. Spot repairs of urgency Classes I and II and partly Class III (about 50,000 orders): Dfl. 30 million.

For repairs following breaking-outs for cables and pipes (about 130,000 orders): Dfl. 25 million.

Within the road department the city employs about 800 people (included 550 paviors and helpers, and 70 apprentices) and about 350 people for management and admini-stration. An additional 500 people or so are employed by contractors.